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A Model of Water Use by Maize

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In order to evaluate the effects of soil moisture conditions on grain yields or on harvesting conditions it is necessary to have a model of crop water use. The different growth stages are considered separately and for each stage the transpiration is assessed relative to the potential transpiration calculated for a short turf surface under the same weather conditions. The term "potential transpiration" always refers to a short turf surface.

Detailed Model

1. Pre-emergence

It is assumed that the fields are in fallow during the Winter and early Spring with no weeds. Sowing takes place at the end of April and emergence normally follows by the third week in May. Therefore evaporation is from bare soil. A system suggested by Smith (1958) is used.

(1) A date is chosen when field capacity is assured, say after some rain in late March.

(2) The first 0.5 in of soil moisture is extracted at the potential rate.

(3) The second 0.5 in of soil moisture is extracted at $^1/_5$ potential rate.

(4) The third 0.5 in of soil moisture is extracted at $^1/_{10}$ potential rate.

2. Emergence to approximately 3 weeks after Emergence (last week in May and first 2-3 weeks in June)

During this time it is assumed that on average the soil is half covered by leaves. Evaporation is from bare soil (as in (1) above) plus a contribution from the plants. Since the plants are seedlings, transpiration from them is assumed to take place at the potential rate for the first inch of soil moisture, at half the potential rate for the next inch and one quarter the potential rate after that.

This gives a scheme of extraction:

(1) First 0.5 in soil moisture at the potential rate.

(2) Second 0.5 in soil moisture at 0.6 potential rate (half the area at the potential rate (plants) and half at $^1/_5$ the potential rate (bare soil)).

/(3)

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(3) Third 0.5 in soil moisture at 0.3 potential rate (half the area at $\frac{1}{2}$ potential rate, and half at $\frac{1}{10}$ potential rate).

(4) Fourth 0.5 in soil moisture at 0.3 potential rate.

(5) Fifth 0.5 in soil moisture at 0.2 potential rate (half the area at $\frac{1}{4}$ potential rate, and half at $\frac{1}{10}$ potential rate).

3. Mid June to Harvest

During this period the ground is assumed to be completely covered by vegetation with no evaporation from the bare soil. The height of the crop increases from 0.5-1.0 m. in June to 1.5-2.0 m. by mid July just before flowering time. After flowering the height is assumed constant.

Some allowance has to be made for the effect of crop height on transpiration. When leaf resistance is small Ag. Mem. 369 suggests that transpiration from maize 1.0 m. tall is approximately the potential rate plus 20-30%. For maize 2.0 m. tall it is approximately the potential rate plus 30-40%. When soil moisture deficits exceed 2" the rate of transpiration from grass is taken to be half the potential rate. If this reduction is due to increasing leaf resistance r_s, then the ratio r_s/r_{ag} has to be roughly 3. (r_{ag} is the resistance to diffusion of water vapour in the air). Under these conditions the difference in transpiration between maize and grass is more uncertain but probably small, and is taken as zero in this model.

Scheme:

(1) First 2.0 in of soil moisture at the potential rate (plus some percentage depending on crop height).

(2) Second 2.0 in of soil moisture at $\frac{1}{2}$ the potential rate.

(3) Next 2.0 in of soil moisture at $\frac{1}{4}$ the potential rate.

Any rain which falls goes at the potential rate plus the appropriate percentage.

Another complication is the effect of senescence on transpiration. During September and October when plant activity is decreasing the leaves loose their function, change their colour and begin to die. This must reduce transpiration, but in an unknown manner. Fortunately potential transpiration is usually small so the error may not be large.

Simplified Model

This scheme is quite complicated and requires data of temperature, sunshine and rain for periods other than the standard months. A simpler method is as follows.

April and May

Evaporation during these months is assumed to be from bare soil with no soil moisture deficit at the end of March. Making use of monthly data, the

/maximum

maximum evaporation is the potential rate with extractions as before:

First 0.5 in at the potential rate.

Second 0.5 in at 1/5 the potential rate.

Third 0.5 in at 1/10 the potential rate.

June

The maximum transpiration is assumed to be the potential rate plus 10% and since the plants do not have a fully developed root system we allow extractions:

First 1.5 in at the potential rate plus 10%.

Second 1.5 in at $\frac{1}{2}$ the potential rate (or 0.45 of the potential rate plus 10%).

Third 1.5 in at $\frac{1}{4}$ the potential rate (or 0.23 of the potential rate plus 10%).

July

The maximum transpiration is the potential rate plus 20% with extractions as follows:

First 2.0 in at the potential rate plus 20%.

Second 2.0 in at $\frac{1}{2}$ the potential rate (or 0.42 of the potential rate plus 20%).

Third 2.0 in at $\frac{1}{4}$ the potential rate (or 0.21 of the potential rate plus 20%).

August

The maximum transpiration is the potential rate plus 30% with extractions as follows:

First 2.0 in at the potential rate plus 30%.

Second 2.0 in at $\frac{1}{2}$ the potential rate (or 0.38 of the potential rate plus 30%).

Third 2.0 in at $\frac{1}{4}$ the potential rate (or 0.19 of the potential rate plus 30%).

September, October

Plant activity is becoming less during these months perhaps accompanied by an increase in albedo. For lack of any basis to work on, the maximum transpiration is assumed to be the potential rate with the usual limitations:

First 2.0 in at the potential rate.

Second 2.0 in at $\frac{1}{2}$ the potential rate.

Third 2.0 in at $\frac{1}{4}$ the potential rate.

/Model

Dates of return to field capacity for maize and grass (Radcliffe, Oxford). No allowance for runoff during heavy rain has been made.

Notation: early October 01
Mid November N2
Late December D3

Year	Maize	Grass
1950	N2	S3
1952	N2	N1
1953	D3	D3
1954	N2	03
1955	D3	D3
1956	N2	N1
1957	02	S3
1958	01	01
1959	D3	D2
1960	S3	S3
1961	D2	D1
1962	N2	N1
1963	N2	N1
1964	MAR 3	MAR 3
1965	D1	N3
1966	02	02
1967	03	03
1968	S1(?)	Jy 3
1969	D3	D3
1970	N3	N3

/Soil

Soil moisture deficits (inches) calculated by the detailed and simplified methods.

E = emergence c.c. = closed canopy F = flowering

1962

	Date	Detailed	Date	Simplified
March	31	0.0	31	0.0
April	30	0.30	30	0.18
May	22 E	0.73	31	0.71
June	21 c.c.	1.94	30	3.06
July	20	2.94		
	31	3.14	31	3.80

1964

March	23	0.0	31	0.0
April	20	0.27	30	0.0
May	17 E	0.80	31	0.70
June	10 c.c.	1.61	30	1.83
July	8	2.98		
	29 F	4.00		
	31	4.07	31	3.57

1967

March	31	0.0	31	0.0
April	30	0.53	30	0.47
May	19 E	0.57	31	0.25
June	19 c.c.	1.55	30	1.97
July	10	2.31		
	31 F	2.68	31	2.76

/1968

1968

	Date	Detailed	Date	Simplified
March	25	0.0	31	0.0
April	25	0.68	30	0.44
May	26 E	0.0	31	0.59
June	18 c.c.	1.30	30	1.62
July	21	0.0		
	31	0.61	31	0.12